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Potential common radiation problems for components and diagnostics in future magnetic and inertial confinement fusion devices

Objectives:

This work aims at identifying common potential problems that future fusion devices will encounter for both magnetic (MC) and inertial (IC) confinement approaches in order to promote joint efforts and to avoid duplication of research.

For this purpose:

1. We compare the radiation environments found in both fusion reaction chambers
2. We discuss about common
   - material issues for divertor/first wall
   - Components and materials for diagnostic systems

Radiation fluxes

•**Similarities:** The harsh environment that both (MC and IC) fusion reaction chambers have to withstand (high fluxes of n, γ, X-rays and energetic light ions).

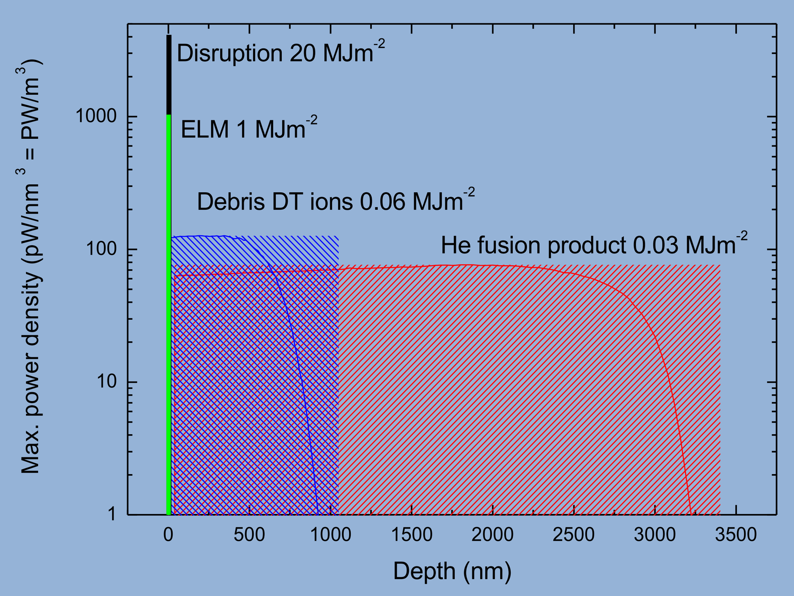
•**Differences:** the radiation pulse length (~ 200 ns for IC and hundreds of seconds for MC).

• *However*, the most remarkable radiation events in MC appear as **prompt emissions**: (i) ELM and (ii) disruptions ⇨*similar thermo-mechanical and atomistic effects ???*

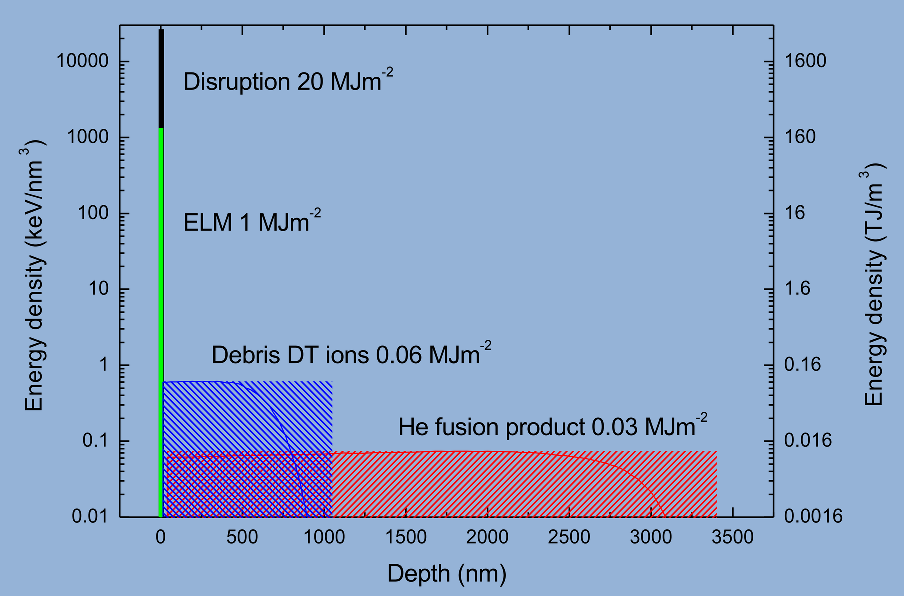
a) Thermal loads:

		Time (s)	Deposited energy (E_d) (MJm^{-2})	Power (MWm^{-2})	Heat flux parameter (H) ($MWm^{-2}s^{-1/2}$)	Particle energy (eV)	Particle flux ($m^{-2}s^{-1}$)
Divertor	steady state	1000	-	15	-	1-30	$<10^{24}$
	ELM	0.2×10^{-3}	1	5×10^{3}	70	1-30	$<10^{24}$
	disruptions	1×10^{-3}	20	2×10^{4}	600	1-30	$<10^{24}$
Direct target	α-particles	200×10^{-9}	0.03	1.5×10^{5}	70	2.1×10^{6} avg.	1×10^{25}
	DT debris	1.5×10^{-6}	0.06	4×10^{4}	50	150×10^{3} avg.	2×10^{22}

Optimistic conditions assumed for ITER divertor and for a typical direct drive target of (yield 154 MJ) [1,2]



Power density as a function of depth in a W sample for different MC and IC conditions



Energy density deposited in a W sample as a function of depth

•E_d in MC events >> than in IC.

•Peak powers in IC > than in MC

•Similar H values are found in MC (ELMs) and IC ⇨ similar thermal effects

b) Ion-induced defects:

•The ingredients for defect-driven phenomena exist in both MC and IC, BUT the implantation species, energies and fluxes drastically diverge ⇨ different damage production.

c) γ–rays and neutrons:

First Wall	Neutron flux ($m^{-2}s^{-1}$)	Neutron Fluence (end of life) (m^{-2})	Dose rate gammas (Gys^{-1})
ITER	$3x10^{18}$	$3x10^{25}$	$2x10^{3}$
IC	$3x10^{16}m^{-2}$ shot equivalent to 10^{25}	10^{20}	10^{11}

Rough neutron fluxes and gamma ray doses assumed for ITER [3] and a inertial direct drive target (yield 154 MJ)

•The effects of γ-rays and neutrons represent a common problem mainly on damage of optical components and activation issues.

REFERENCES:

[1] T. Eich et al. J. Nucl. Mater. 313-316, 759 (2003).
[2] http://aries.ucsd.edu/ARIES/WDOCS/ARIES-IFE/SPECTRA/
[3] J.L. Bourgade et al. Rev. Sci. Instrum. 79, 10F304 (2008)

Common material issues for divertor/first wall

•W and C-based are the materials most promising for MC divertor and IC armor.

a)From a thermo-mechanical point of view:

Problems: None of the existing materials can withstand the most disadvantage radiation conditions

•The IC community is working on developing large surface area and high thermal conductivity materials. Common research can be done in this area.

b) From an atomistic point of view:

Problems: light species (He, D and H) nucleation which degrades material properties → common work can be done on developing porous and self-healing materials.

Common components and materials for diagnostic systems

•Four areas have been identified where collaboration could be of mutual benefits: optical components, MI cables, electronics and neutron diagnostics.

a)optical components (fibres, window and mirrors)

•*Problems*: radiation –induced absorption (RIA) and radiation-induced luminescence (RIL)

- **Windows**: It is of mutual interest to investigate means to reduce RIL and a common effort can be done to examine the possibility of high temperature operation and in-situ annealing to reduce RIA.
- **Fibres**: Collaboration can be done on necessary radiation testing, jacketing suitable for high T operation, exchange of candidate fibres, and a joint programme to define and control fibre fabrication parameters

b) Cables

•*Problems*: different kind of cables MI (mineral insulated) for MC (low V and low F applications) and standard PTFE/CH (high F dielectric cables) ➪ the interchange of data concerning the influence of RIC (radiation induced conductivity), RIEMF (radiation induced electromotive force), and possibly TIEMF (temperature induced electromotive force) on measured signals, as well as potential mitigation methods is an area of mutual interest.

b) Electronics

•*Problems*: radiation-induced damage hampers the electronic components to properly work in a radiation environment ➪ working together on the design of basic circuits employing more radiation resistant discrete components (transistors) is desired.

Conclusions

•The common development of advance materials able to satisfactorily withstand the thermo-mechanical and atomistic effects will be a step forward in our way to fusion.

•The damage due to neutrons and gamma rays, mostly on optical components and diagnostic devices also paves the way for a joint investigation

Joint research is not only desirable but also beneficial for both MC and IC communities in their goal to achieve energy by fusion